PRODUCTIVITY IMPROVEMENT IN ECOWAS MILLET FARMING

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Abstract

This study used stochastic production frontier analysis to assess productivity growth of millet in Economic Community of West African States (ECOWAS). The data were collected from Food and Agriculture Organization Statistical (FAOSTAT) database and covered a 45 year period (1961–2005) separated into pre-ECOWAS (1961–1978) and ECOWAS (1979–2005). The results show that: (1) there has been a productivity improvement in the sector, in the interval 0.7–15% in the periods studied and (2) technical change has had the greatest impact on productivity, indicating that producers have a tendency to catch-up with the front runners. The average TFP in pre-ECOWAS period is larger than that of ECOWAS period. In both periods, productivity growth is sustained through technological progress.

Key words: efficiency, technological progress, productivity growth, ECOWAS

INTRODUCTION

Millets (Pennisetum glaucum (L.) R. Br.), are essential to diets of people in the semi-arid tropics where droughts often cause frequent failures of other crops. They are most important in West Africa especially Sahelian part of ECOWAS sub region, where they take about 70% of total cereal production. Generally, pearl millet is planted on about 28 million ha, mainly in Africa and India, to produce 10 million tons of grain per year for about 70 million people. Pearl millet is particularly adapted to Sahelian West Africa where landraces have evolved in different ecological niches. In five major producing countries in ECOWAS region namely Burkina Faso, Mali, Niger, Nigeria and Senegal, more than half of their population depends on pearl millet for over 1000 calories per person per day. The yields of millet may be low under the area's environmental conditions but they are relatively the most dependable staple crop. The percentage of millet used for domestic food consumption is rising steadily in Africa, but the vast and still expanding millet areas continue to produce low, but steady, yields with little or no usage of modern technologies. At present, Africans eat about four times as much millet per capita as the second largest consumers, after Asians. Figure 1 indicates that the productivity in major producing countries in ECOWAS has been consistently low even after establishment of ECOWAS in 1975.

Paramount among the yield reducing factors are predominant cultivation of inherently low yielding varieties, poor soil fertility, drought, Striga, pests and diseases. Exploitation of host-plant resistance through genetic enhancement has always been the first approach or forms the basis of an integrated control package in addressing these constraints. The relative limited processing, utilization and marketing of millet also present a disincentive to farmers in adopting improved technologies for greater impact. The various National Agricultural Research Systems (NARS) either separately or in collaboration with the international research centres like ICRISAT, INTSORMIL and the regional cereal networks have drawn up research strategies to address the constraints facing the production, processing and utilization of millet. Though a lot of research on millet breeding has been done and documented within and without the continent of Africa there is still a lot to be done looking at the current persistent constraints.

Prior to market liberalization, considerable government intervention helped marginal farmers remain in business in the region. A more open market would be expected to induce some marginal farmers to retire from farming, which means that average current productivity would be

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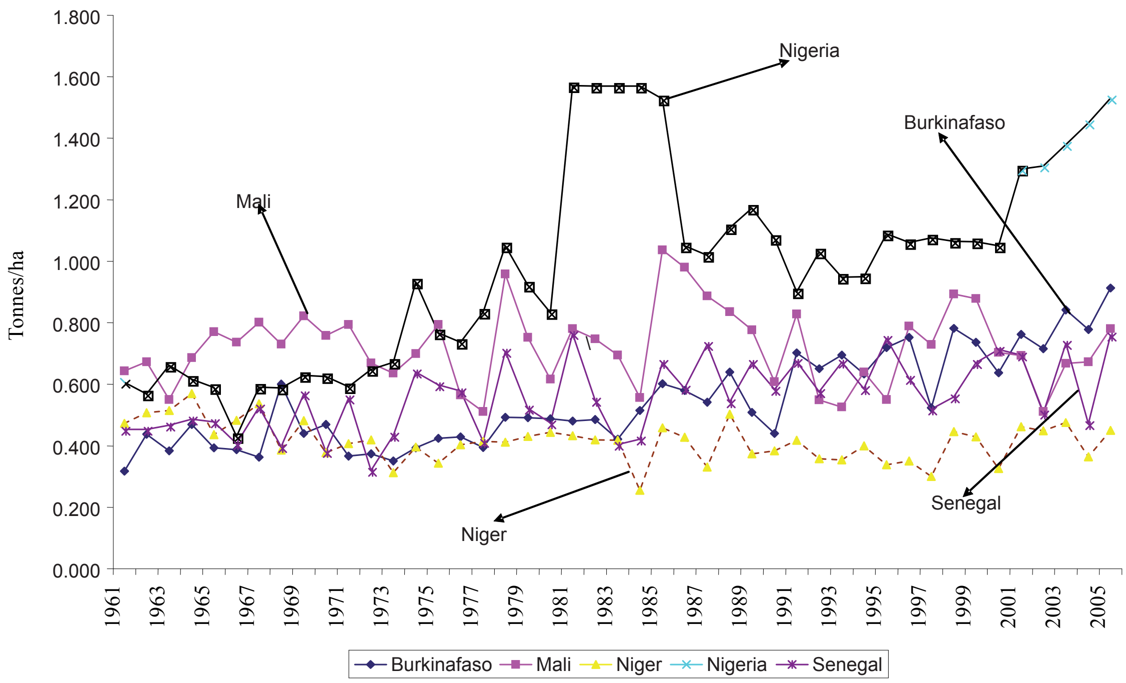
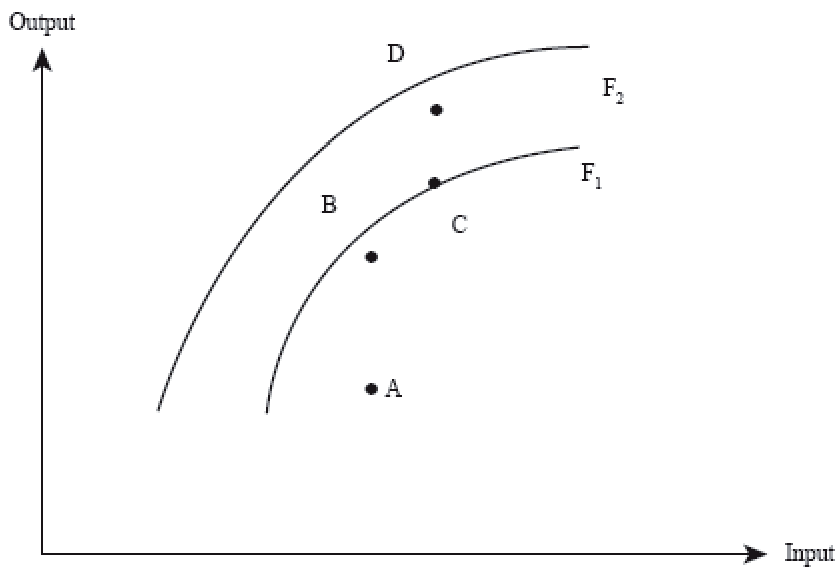
Figure 1: Productivity of millet in major ECOWAS producing nations



misleading as an assessment of the productivity potential. This underscores the relevance of frontier method adapted in this study to measure productivity. The underlying economic reason of the liberalization policy was the low productivity in the pre-liberalization period and expectation that productivity would improve after transition to market economy. In the wake of ECOWAS efforts towards market liberalization reforms, the expected benefits of total factor productivity (TFP) growth can be represented using the production frontier shown in Figure 2. The production frontier traces out the maximum output obtainable from the use of inputs. In the figure below, F_1 and F_2 are the production possibility frontiers in time 1 and 2 respectively. Opportunities from market liberalization reforms can lead to:

(a) shift from A to B due to technical efficiency
(b) shift from B to C on existing frontier due to input growth
(c) upward shift from C to D due to technological progress

Figure 2: Total factor productivity gains from market liberalization reforms



Source: Mahadevan and Kalirajan (1999)

Each of the above-mentioned shifts, which constitute various sources of TFP growth, can be linked with trade gains. The movement from A to B led by technical efficiency allows increases in output when inputs and technology are used to their fullest potential to obtain the greatest yield. Given that ECOWAS has been involved in agricultural production for so long, there would be learning-by-doing gains that can help boost production given the expected increase in demand as ECOWAS opens up her market economy. The increased production would enable a better utilization of inputs, especially that of advanced capital technology.

The move from an overvalued exchange rate to that of a market determined rate would also make agricultural exports cheaper and hence boost exports. The new trading opportunities would necessitate an increased use in the quantity of inputs to boost output and this allows for the movement from B to C along the existing production possibility frontier. Increased exports would bring about economies of scale and output growth would lead to productivity growth. The scale of output under increased exports would justify the huge fixed costs underlying technologically advanced equipment and hence increase incentives to adopt high quality inputs. The use of such inputs would result in technological progress and this is represented by the shift from C to D.

While much evidence has been provided attesting the productive performance of the agricultural sector in Africa and factors influencing it (Thirtle and Townsend, 1995; Coelli and Rao 2001; Nkamleu et al., 2004, 2008) there is little evidence on crop-specific and sub-regional productive performance. An assessment of crop-specific efficiency and productivity analysis should be of more interest to policy-makers implementing liberalization policy than overall aggregates. The rationale is twofold; (1) an insight can be gained on the potential for resource savings and productivity improvements of individual crops and, (2) the producers can learn from the front-runners how best to utilize their resources efficiently. Inter alia, issues of interest in this study are: (a) Is there any potential for improving the efficiency of millet producers in ECOWAS? If so, what are the magnitudes? (b) Has there been any productivity progress in ECOWAS millet production since 1979? The choice of 1979 as reference point is to account for periods before ECOWAS policies become effective in member states.

The rest of this paper is organized as follows: section 2 presents the theoretical foundation for the stochastic measurement of the TFP and empirical evidence of its application is presented in section 3. Also the data used are described and the parameter estimates are reported to infer which factors explain the growth of output. A final section concludes.

MATERIALS AND METHODS

Stochastic frontier method

The stochastic production function for panel data can be written as

$$\ln(y_{it} = f(x_{it}, t, \alpha, v_{it} - u_{it}) \quad (1)$$

$i = 1, 2, \dots N$ and $t = 1, 2, \dots T$ (Battese and Coelli, 1992)

where y_{it} is production of the i^{th} firm in year t, α is the vector of parameters to be estimated. The v_{it} are the error component and are assumed to follow a normal distribution $N(0,\sigma^2_{it})$, u_{it} are non negative random variables associated with technical inefficiency in production which are assumed to arise from a normal distribution with mean μ and variance σ^2_μ which is truncated at zero $f(.)$ is a suitable functional form (e.g translog), t is a time trend representing the technical change.

In this parametric case, according to Coelli et al. (1998), the technical efficiency are obtained as

$$TE_{it} = E(\exp)(-u_{it}) / v_{it} - u_{it}) \quad (2)$$

This can be used to compute the efficiency change component by observing that $TE_{it} = d^t_o(x_{it}, y_{it})$ and $TE_{i,\,t+1} = d^{i,\,t+1}_o(x_{i,\,t+1}, y_{i,\,t+1})$ the efficiency change (EC) is

$$EC = TE_{it} / TE_{i,t+1} \quad (3)$$

An index of technological change between the two adjacent periods t and $t+1$ for the i^{th} region can be directly calculated from the estimated parameters of the stochastic production frontier by simply evaluating the partial derivatives of the production function with respects to time at x_{it} and $x_{i,\,t+1}$. Following Coelli et al. (1998), the technical change (TC) index is

$$TC_{it} = \left\{ \left[1 + \frac{\delta f(x_{it}, t+1, \alpha)}{\delta t + 1} \right] X \left[1 + \frac{\delta f(x_{it}, t, \alpha}{\delta t} \right] \right\}^{1/2} \quad (4)$$

The TFP index can be obtained by simply multiplying the technical change and the technological change i.e

$$TFP_{it} = EC_{it} \times TC_{it} \quad (5)$$

Empirical specification

This study utilized data on output and inputs of millet, from major producers of the crops to construct indices of TFP using the model described by equations 1–5. The sample data comprise annual measures of the output of millet and 5 direct inputs (land area, seed, labour, fertilizer and capital). The major countries producing millet are: Burkina Faso, Mali, Niger, Nigeria, and Senegal. For the purpose of the present study, several functional forms were fitted beginning with Cobb-Douglas technology. The underlying stochastic production frontier function upon which the results and discussion of this study are based is approximated by the generalized Cobb-Douglas form (Fan, 1991). The function may also be viewed as a translog specification without cross terms, i.e. a strongly separable-inputs translog production frontier function. The specification is:

$$\ln y_{it} = \alpha_0 + \alpha_h \ln H_{it} + \alpha_s \ln S_{it} + \alpha_f \ln F_{it} + \alpha_l \ln L_{it} + \alpha_k \ln K_{it} + \alpha_t t + \alpha_{tt} t^2 + \alpha_{ht} \ln(H_{it})t + \alpha_{st} (\ln S_{it})t + \alpha_{ft} (\ln F_{it})t + \alpha_{lt} (\ln L_{it})t + \alpha_{kt} (\ln K_{it})t + \mathrm{v}_{it} - u_{it}\, t \quad (6)$$

Where:

y_{it} = the output of crop i in the t^{th} year
H_{it} = the hectares of land cultivated to each crop
S_{it} = the quantity of seed planted in 1000 tonnes
F_{it} = the quantity of fertilizer used in 1000 tonnes
L_{it} = amount of labour used in mandays
K_{it} = the amount of capital used
t = the time trend
ln = the natural log
$\alpha_i s$ = unknown parameters to be estimated
$v_{it}s$ = $iidN(0, \sigma_{v^2})$ random errors and are assumed to be independently distributed of the $u_{it}s$ which are non negative random variables associated with TE inefficiency. The distribution of the $u_{it}s$ are obtained by truncation at zero. The mean is defined as:

$$u_{it} = \beta_0 + \beta_1 \frac{K_{it}}{L_{it}} + \beta_{dj} \sum_{j=1}^{n} D_{tj} + \beta_{tj} \sum_{j=1}^{n} D_{tj} t \quad (7)$$

Where

$\frac{K_{it}}{L_{it}}$ = capital – labour ratio for crop i in the t^{th} year
D_j = the dummy variable which takes the value of 1 for the j^{th} state producing the crop
Bs = unknown parameters to be estimated

Data description

data for inputs and outputs are collected principally from FAOSTAT 2007. The data covered a period of 45 years from 1961 to 2005. The data cover Burkina Faso, Mali, Niger, Nigeria and Senegal. The selected countries accounted for more than 90% production of millet in ECOWAS. The data set contains four inputs namely land area, seed, fertilizer, labour, and country dummies. The descriptions of the input-output data used in this study are:

Outputs

The Quantity of millet production in metric tonnes. This is taken from FAOSTAT database.

Inputs

Fertilizer: Fertilizer use is proxyed as the total fertilizer use in each country times the share of the crop harvested fields in total arable land (UN, FAO).

Labour: This is measured as the amount of labor in each crop production proxyed as the economically active agricultural labor force per unit of agricultural land times each crop harvested area (FAO). Some studies have used active workers in rural areas (World Bank). This was tried also but the results were not as good as when the former was used.

Capital: Capital as used in this study refers to the amount of capital used in each crop production. It is proxyed as tractors used per unit of agricultural land times rice-harvested area(UN FAO).

Land: Expressed 1000 ha, it is measured as individual land area under each crop. Land data is also drawn from FAOSTAT data base.

Seed: Drawn from FAOSTAT data base and expressed in 1000 metric tons, it covers quantity of each crop seed planted.

The descriptive statistics for the inputs and output are summarized in Table 1. The Table contains the mean value and standard deviation of millet producing nation by year as well as by reform periods. In terms of the means across the reform periods, it is clear from the table that there is a variation in both inputs and outputs among the countries. Millet output from Burkina Faso for instance, is up to four times as high as that achieved by Niger while output from Nigeria is about twice as that achieved by Burkina Faso. The input usage follows the same trend. For example, Nigeria is using up to four times the amount of land employed by Niger. In terms of standard deviation, large values are observed with respect to both output and inputs for all the crops. The figures show that both output and input values are generally higher in ECOWAS era than pre-ECOWAS.

RESULTS AND DISCUSSION

The results of the stochastic frontier model

Parametric productivity measures are based on the estimated parameters of the stochastic frontier function (6), and so a brief discussion of these estimates and their statistical properties precedes our comparative analysis of productivity indices. The estimated parameter of the stochastic quasi translog production frontier function is estimated using FRONTIER 4.1 software (Coelli, 1996). The parameter estimates of the model for the whole period (1961–2005), pre-ECOWAS period (1961–1978) and ECOWAS period (1979–2005) are presented in Table 2.

Tab. 1: Millet descriptive statistics

Variable	1961–1978		1979–2005		1961–2005	
	average	standard deviation	average	standard deviation	average	standard deviation
BURKINA FASO						
Annual output (kg)	321 857.28	57 921.23	728 363.26	248 118.27	565 760.87	279 704.84
Land (ha)	775 176.00	96 236.80	1 127 030.70	198 295.56	986 288.82	239 167.78
Seed (kg)	11 754.81	1 314.94	17 090.59	2 740.99	14 956.28	3 477.90
Fert (kg)	507.59	848.12	5 719.71	4 272.60	3 634.86	4 211.06
Tractor used	5.64	2.46	136.30	101.93	84.04	101.65
Labour used	273 748.19	41 744.85	510 544.92	127 842.76	415 826.23	155 223.29
MALI						
Annual output (kg)	449 777.78	52 013.07	761 070.15	199 948.36	636 553.20	220 124.24
Land (ha)	643 833.33	108 189.51	1 067 938.15	310 579.72	898 296.22	325 069.20
Seed (kg)	19 031.67	3 201.32	32 201.32	7 655.28	26 933.46	9 008.91
Fert (kg)	1 708.56	1 775.55	9 399.13	4 377.47	6 322.90	5 201.78
Tractor used	9.98	5.74	64.04	29.38	42.42	35.22
Labour used	54 087.30	11 112.45	123 219.99	41 810.12	95 566.91	47 473.98
NIGER						
Annual output (kg)	903 622.22	157 912.30	1 735 260.48	509 129.02	1 402 605.18	576 686.42
Land (ha)	2 083 455.56	346 545.15	4 335 816.15	1 056 529.45	3 434 871.91	139 6863.30
Seed (kg)	32 320.15	5 702.57	64 443.80	13 697.93	51 594.34	19 409.54
Fert (kg)	109.93	165.78	1 258.07	871.17	798.81	884.67
Tractor used	2.80	2.45	17.23	3.99	11.46	7.93
Labour used	145 879.21	45 649.69	509 127.14	185 451.00	363 827.97	231 333.58
NIGERIA						
Annual output (kg)	2 841 944.44	606 745.27	4 678 962.96	1 399 677.20	3 944 155.56	1 458 836.40
Land (ha)	4 289 555.56	753 003.88	4 056 777.78	1 289 582.29	4 149 888.89	1 102 301.73
Seed (kg)	67 037.33	13 681.08	71 582.81	24 203.24	69 764.62	20 580.10
Fert (kg)	3 105.18	3 386.32	33 705.71	17 460.77	21 465.50	20 357.50
Tractor used	225.65	182.33	1 420.12	745.39	942.33	831.48
Labour used	926 414.45	174 561.11	878 043.17	281 723.27	897 391.68	243 406.44
SENEGAL						
Annual output (kg)	434 266.67	108 419.60	539 558.19	129 216.81	497 441.58	130 878.63
Land (ha)	877 150.00	78 430.05	880 236.26	100 802.90	879 001.76	91 560.51
Seed (kg)	26 437.83	2 172.66	26 394.46	3 033.65	26 411.81	2 694.89
Fert (kg)	8 005.67	5 388.36	8 837.18	2 699.27	8 504.57	3 961.43
Tractor used	31.99	9.15	59.39	9.13	48.43	16.31
Labour used	194 280.41	30 365.46	308 595.94	50 034.64	262 869.73	71 015.36

Tractor and labour used are expressed in actual numbers engaged in millet production in each nation

Tab. 2: Maximum Likelihood Estimates of the stochastic frontier model

Coefficient	1961–2005		1961–1978		1979–2005	
	estimate	t-ratio	estimate	t-ratio	estimate	t-ratio
α_0	6.08	5.61	–0.65	–0.86	12.07	10.88
α_h	0.47	2.55	1.00	3.83	0.38	1.16
α_s	0.14	0.87	0.25	0.91	0.19	0.58
α_f	0.027	0.81	0.17	0.32	0.15	1.81
α_k	–0.05	–0.80	0.045	0.72	0.34	4.54
α_l	–0.012	–0.13	–0.21	–1.89	–0.66	–3.09
α_t	0.0088	0.30	0.22	2.23	–0.042	–0.67
0.5 α_{tt}	–0.00013	–0.49	0.00022	0.098	0.0013	2.09
α_{ht}	0.0077	1.16	–0.0087	–0.39	0.014	1.32
α_{st}	–0.012	–1.83	–0.015	–0.68	–0.0073	–0.65
α_{ft}	–0.0010	–0.93	0.0011	0.25	–0.0036	–1.59
α_{kt}	0.0041	2.83	0.0073	1.35	–0.0016	–0.73
α_{lt}	0.0013	0.38	0.0029	0.25	–0.0057	–0.82

*, +, ^ indicate significant at 1, 5, and 10% respectively
EFFCH means efficiency change, TECH means technical change, and TFP means total factor productivity

The variance parameters, σ^2 and γ are significantly different from zero. This provides statistical confirmation of the presumption that there are differences in technical efficiency among farmers. The mode of the truncated normal distribution μ is significantly different from zero, providing statistical evidence that the distribution of the random variable μ has a non-zero mean and is truncated below zero. The ratio of the country specific variability to total variability measured by γ is positive and significant at 1% significant level for all the crops. This implies that the country specific technical efficiency is important in explaining the total variability of rice output produced in ECOWAS. Thus the stochastic frontier production function is empirically justified. Further, the statistical significance of modeling country effects is further examined using likelihood ratio tests. The logarithm of the likelihood function indicates a satisfactory fit for the generalized Cobb Douglas specification. The statistical significance of all of the parameters, σ^2, γ, and L, reinforces the view that technical efficiency affects productivity.

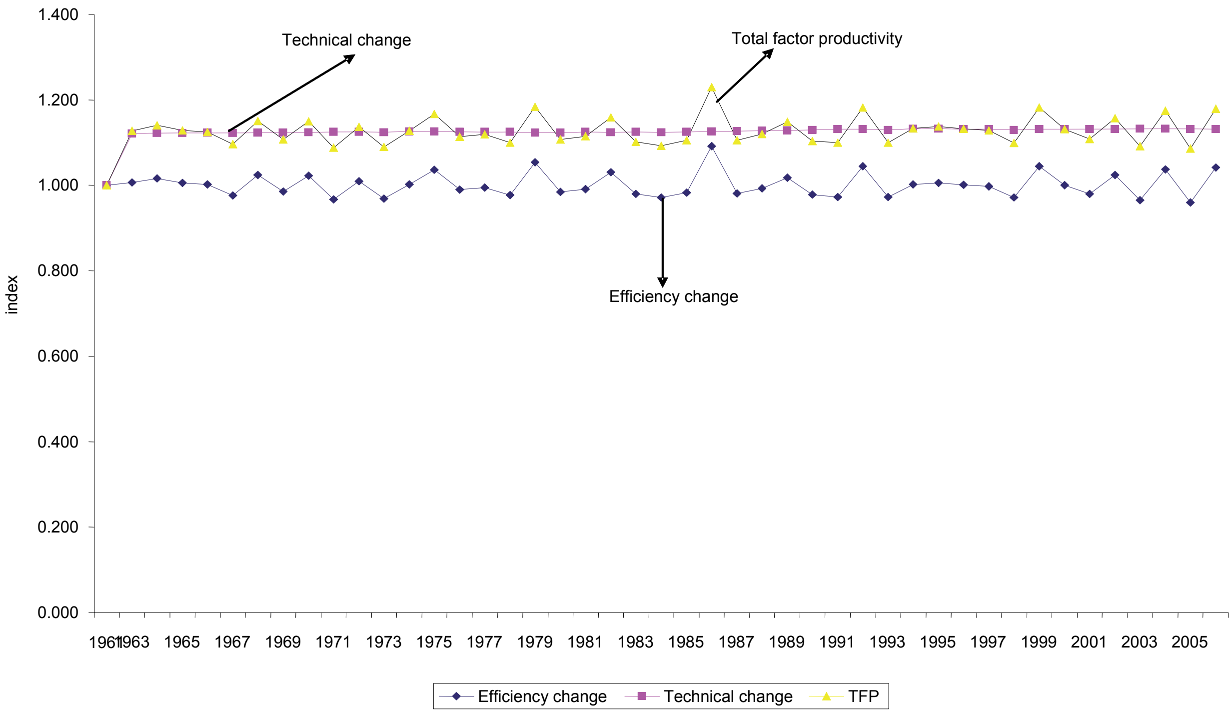
The results of the Maximum Likelihood Estimates show that the number of statistically significant vari-

Tab. 3: Maximum Likelihood Estimates (MLE) of the inefficiency model

Coefficient	1961–2005		1961–1978		1979–2005	
	estimate	t-ratio	estimate	t-ratio	estimate	t-ratio
β_0	0.51	1.15	–0.57	–1.23	0.12	0.27
β_1	0.013	0.024	3.33	2.82	1.26	1.61
β_2	0.65	1.54	0.34	0.79	0.017	0.042
β_3	0.25	0.62	–0.053	–0.13	0.99	2.32
β_4	0.22	0.53	0.39	0.87	–0.16	–0.37
β_5	–1.15	–2.74	–1.26	–2.54	–1.16	–2.53
β_6	0.54	1.30	0.11	0.26	0.44	1.05
σ^2	0.028	11.20	0.029	4.06	–0.040	6.39
γ	0.21	4.25	0.60	4.75	0.99	181.15
L	97.06		48.77		66.55	

EFFCH means efficiency change, TECH means technical change, and TFP means total factor productivity

Figure 3: Evolution of millet efficiency change, technical change and total factor productivity



ables is few but their coefficients conform to a prior expectation of positive sign except labour. This indicates over-utilization of labour input. The over-utilization of labour continues in the reform period. The coefficient of capital is positive in both reform periods. It is however significant only in the reform period. Capital-labour ratio has positive but insignificant impact on millet technical efficiency over the entire analysis period. However, a 1% increase in capital-labour ratio will cause about 3.3% and 1.26% increase in millet technical efficiency in pre-reform and reform era respectively. The coefficient on the time trend indicates positive technological progress in millet production over the entire analysis period (1961–2005), the frontier is shifting upwards at annual rate of about 0.9%. The technological progress actually takes place in the pre-ECOWAS era as the results indicate technological decline in the reform period.

The evolution of the Malmquist productivity indices and the associated efficiency and technical components covered in the analysis from 1961–2005 are shown in Figure 3 while the results for each country in the sample are presented in Table 4. It should be noted that if the value of the Malmquist index or any of its components is less than one, it implies regress between two adjacent periods, whereas values greater than 1 imply progress or improvement. In order to obtain the magnitude of progress or regress, the values of Malmquist indices or any of its components can be subtracted from 1. The values of the indices capture productivity relative to the best

Tab. 4: Total factor productivity by reform periods: SFA

Country	1961–2005			1961–1978			1979–2005		
	EFFCH	TECH	TFP	EFFCH	TECH	TFP	EFFCH	TECH	TFP
					Millet				
B. Faso	1.002	1.124	1.126	1.002	1.119	1.121	1.002	1.127	1.129
Mali	1.002	1.119	1.120	1.002	1.115	1.117	1.001	1.121	1.123
Niger	1.002	1.126	1.128	1.001	1.120	1.121	1.002	1.131	1.133
Nigeria	1.000	1.144	1.144	1.000	1.143	1.143	1.000	1.144	1.144
Senegal	1.002	1.122	1.124	1.007	1.122	1.129	1.000	1.121	1.121
Mean	1.002	1.127	1.128	1.002	1.124	1.126	1.001	1.129	1.130

EFFCH = means efficiency change; TECH = means technical change; TFP = means total factor productivity performers. In this study, the Malmquist indices measure year to year changes in productivity.

The results of TFP and its decomposition for millet in Figure 3 show an impressive technical progress during the sample period. The estimates show that the technical progress varies from 12–13%. The progress is very much pronounced in the ECOWAS period. From 1991 for instance, there is upward movement in both efficiency and technical change and hence the TFP. Throughout 1961–2005, ECOWAS sub region has efficiency change approximately equal to one suggesting that the region remained on the technology frontier in respect of millet. Though results from other sub region producing millet are not available it's most likely that ECOWAS will be the region that define production frontier for others producing the crop.

The country level breakdown shown in Table 4 shows that the average TFP growths are 1.126, 1.120, 1.128, 1.143 and 1.124 for Burkina Faso, Mali, Niger, Nigeria and Senegal respectively, the TFP growth is due mainly to technical change rather than efficiency change. The rate of growth from 1979 is almost the same with the rate of decline from 1961–2005. A comparison of the results of different reform era shows that all the countries have positive TFP in all the periods. The results are however more robust in ECOWAS period than in pre-ECOWAS era. The rate of growth is lower in pre-ECOWAS than in ECOWAS period in all the countries, except Senegal. The improvement in TFP in ECOWAS period over pre-ECOWAS is however driven by Nigeria whose TFP growth is 1.143.

CONCLUSIONS

The present research applied a parametric model to a sample of panel data of ECOWAS millet production for the period of 1961–2005. The productivity growth was estimated using the Malmquist index. The productivity measures are decomposed into two sources of growth namely efficiency change and technical change. The results show evidence of phenomenal growth in the TFP. A closer look at the TFP in ECOWAS and pre-ECOWAS sub-period shows larger TFP in ECOWAS period (1979–2005). In both periods, the productivity growths are sustained through technological progress. Several inferences may now be drawn from the results. First, inefficiency and productivity growth exists among millet producing countries in ECOWAS. The magnitude of inefficiency and the extent of productivity growth that has taken place vary from country to country. Second, examining the components relating to the shift in the frontier (TC) and efficiency change (EC), technical change turned out to be a more important source of growth.

A limitation of the study is that the data used as shown in the yield curves tend to fluctuate considerably. This means that the productivity measures are based on low productivity year. Also a six country panel data may be relatively short to draw convincing results on variation in productivity among the producing country. It is unlikely that the differences in productivity among the countries can be sustained rather it is confined to the specific data period and countries. Despite the caution in interpreting the results, the following policy recommendations are suggested from the findings:

1. The government of the major producers of millet should invest more in functional agricultural extension services to enhance efficient use of available productivity increasing inputs.
2. Given differences in the contribution of efficiency change and technological progress to the TFP ECOWAP should take a leave from EU CAP, by marrying policy with specific crop need.
3. Future works should quantify parametrically, further the determinants of the productivity growth in the crop.

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